

DUNE Status Report

André Rubbia (ETH Zürich)

On behalf of the DUNE Collaboration

Fermilab PAC Meeting

Wednesday January 20th, 2016

DUNE: An International Collaboration

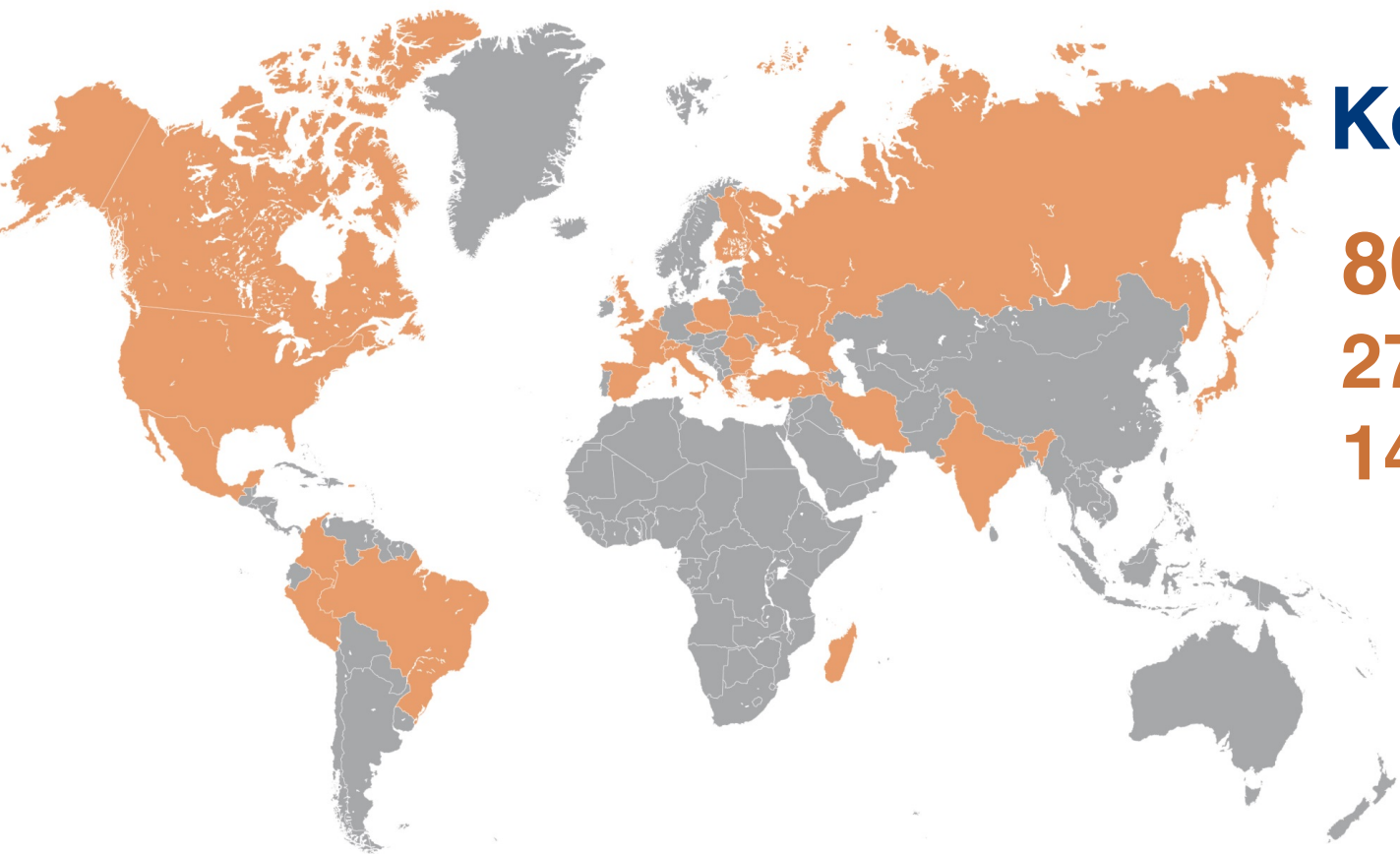
A rapidly evolving international scientific collaboration built around the organisation model successfully implemented at the LHC

- First formal collaboration meeting April 16th - 18th 2015
- Conceptual Design Report (4 volumes) June 2015
- Passed DOE CD-1 Review July 2015
- Second collaboration meeting September 2nd - 5th 2015
- DOE CD-3a Review December 2015
- Third collaboration meeting UTA, Texas January 12th - 15th 2016
 - Over 150 people attending in person
- Fourth collaboration meeting SDSMT, South Dakota May 2016
- Collaboration meetings at FNAL (Sep 16) & CERN (Jan 2017)



Photo taken during 2nd Collaboration meeting

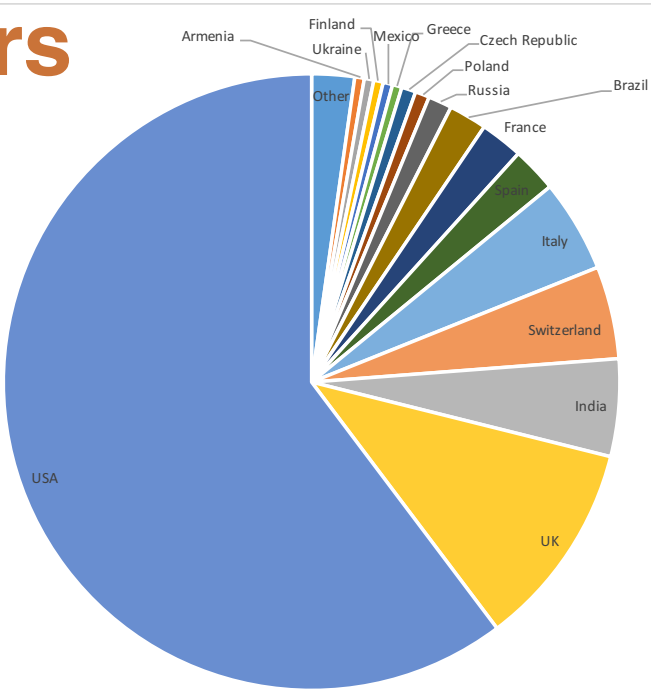
The DUNE Collaboration



Keeps growing:

805 Collaborators
27 Nations
146 institutions

Greece and Finland recently joined



Armenia Yerevan Inst. for Theoretical Physics and Modeling
Belgium Univ. de Liege
Brazil Univ. Federal do ABC; Univ. Federal de Alfenas em Poços de Caldas; Univ. de Campinas; Univ. Estadual de Feira de Santana; Univ. Federal de Goias; Observatorio Nacional
Bulgaria Univ. of Sofia
Canada York University
Colombia Univ. del Atlantico
Czech Republic Charles University, Prague; Czech Technical University, Prague; Institute of Physics ASCR, Prague
France Lab. d’Annecy-le-Vieux de Phys. des Particules; Inst. de Physique Nucleaire de Lvon; APC-Paris; CEA/Sacla
Finland Jyväskylä
Greece Athens
India Aligarh Muslim University; Banaras Hindu University; Bhabha Atomic Research Center; Univ. of Delhi; Indian Inst. of Technology, Guwahati; Harish-Chandra Research Institute; Indian Inst. of Technology, Hyderabad; Univ. of Hyderabad; Univ. of Jammu; Jawaharlal Nehru University; Koneru

Lakshmaiah; Univ. of Lucknow; Panjab University; Punjab Agri. University; Variable Energy Cyclotron Centre
Iran Inst. for Research in Fundamental Sciences
Italy Lab. Nazionali del Gran Sasso, Assergi; Univ. di Catania; Gran Sasso Science Institute; Univ. di Milano; INFN Sezione di Milano Bicocca; INFN Sezione di Napoli; Univ. of Padova; Univ. of Pavia, INFN Sezione di Pavia; CNI Pisa; Univ. di Pisa
Japan KEK; Kavli IPMU, Univ. of Tokyo
Madagascar Univ. of Antananarivo
Mexico Univ. de Colima; CINVESTAV
Netherlands NIKHEF
Peru PUCP
Poland Inst. of Nuclear Physics, Krakow; National Centre for Nuclear Research, Warsaw; Univ. of Warsaw; Wroclaw University
Romania Horia Hulubei National Institute
Russia Inst. for Nuclear Research, Moscow
Spain Inst. de Fisica d’Altas Energias, Barcelona; CIEMAT; Inst. de Fisica Corpuscular, Madrid
Switzerland Univ. of Bern; CERN; ETH Zurich

Turkey TUBITAK Space Technologies Research Institute
Ukraine Kyiv National University
United Kingdom Univ. of Cambridge; Univ. of Durham; Univ. of Huddersfield; Imperial College of Science, Tech. & Medicine; Lancaster University; Univ. of Liverpool; University College London; Univ. of Manchester; Univ. of Oxford; STFC Rutherford Appleton Laboratory; Univ. of Sheffield; Univ. of Sussex; Univ. of Warwick
USA Univ. of Alabama; Argonne National Lab; Boston University; Brookhaven National Lab; Univ. of California, Berkeley; Univ. of California, Davis; Univ. of California, Irvine; Univ. of California, Los Angeles; California Inst. of Technology; Univ. of Chicago; Univ. of Cincinnati; Univ. of Colorado; Colorado State University; Columbia University; Cornell University; Dakota State University; Drexel University; Duke University; Fermi National Accelerator Lab; Univ. of Hawaii; Univ. of Houston; Idaho State University; Illinois Institute of Technology; Indiana University; Iowa State

University; Kansas State University; Lawrence Berkeley National Lab; Los Alamos National Lab; Louisiana State University; Univ. of Maryland; Massachusetts Institute of Technology; Michigan State University; Univ. of Minnesota; Univ. of Minnesota (Duluth); Univ. of New Mexico; Northwestern University; Univ. of Notre Dame; Ohio State University; Oregon State University; Pacific Northwest National Lab; Univ. of Pennsylvania; Pennsylvania State University; Univ. of Pittsburgh; Princeton University; Univ. of Puerto Rico; Univ. of Rochester; SLAC National Accelerator Lab; Univ. of South Carolina; Univ. of South Dakota; South Dakota School of Mines and Technology; South Dakota Science And Technology Authority; South Dakota State University; Southern Methodist University; Stanford University; Stony Brook University; Syracuse University; Univ. of Tennessee; Univ. of Texas at Arlington; Univ. of Texas at Austin; Tufts University; Virginia Tech; Wichita State University; College of William and Mary; Univ. of Wisconsin; Yale University



An Experimental Program in Neutrinos, Nucleon Decay and Astroparticle Physics Enabled by the Fermilab Long-Baseline Neutrino Facility

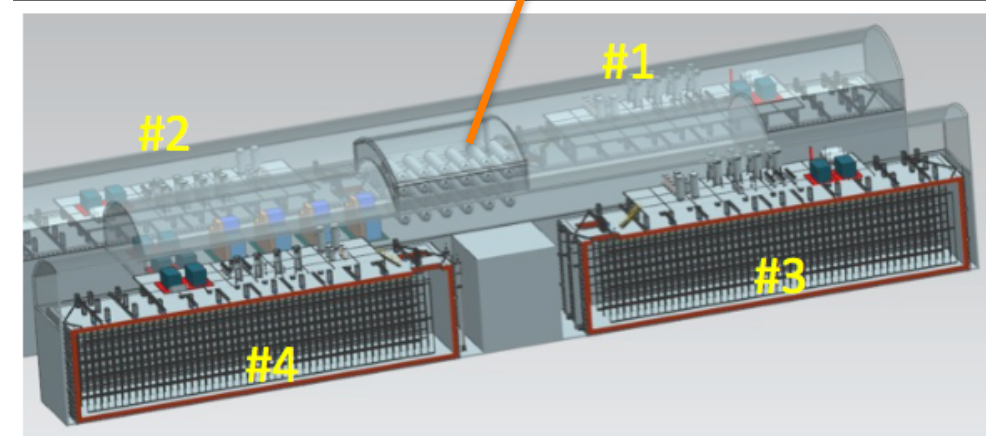
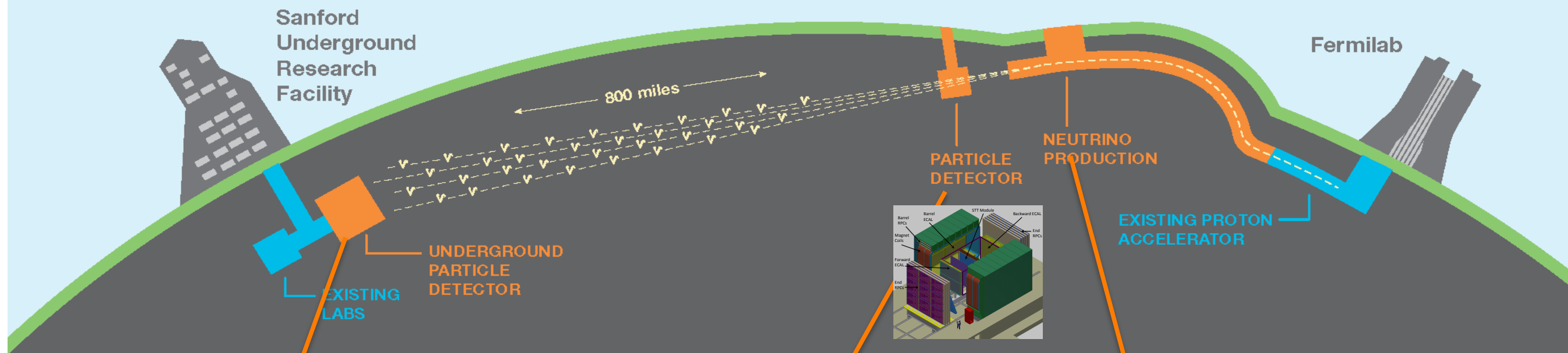


- The **DUNE international Collaboration** has been formed **merging strengths and expertise from all previous efforts** (LBNE, LBNO, others) to carry out a next-generation long-baseline neutrino experiment hosted at Fermilab.
- The Collaboration has adopted and integrated several design options.

	LBNE (FNAL)	LBNO (CERN)	LBNF/DUNE
Baseline	1300 km	2300 km	1300 km
Protons power	1.2 MW	0.75 & 2 MW	1.2 MW then upgrade to 2.4 MW
Beam focusing	NUMI-style	CP-optimised	NUMI-style or CP-optimised
Far detector	10+30 kton	20+50 kton	4x10 kton
Far detector technologies	single phase LAr TPC	dual phase LAr TPC	single and/or dual phase LAr TPC
Near detector design	Magnetised fine grained tracker (FGT)	HP GAr TPC	Magnetised FGT and/or LAr TPC and/or HP GAr TPC

DUNE Experimental Strategy

“Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) Conceptual Design Report Volume 2: The Physics Program for DUNE at LBNF” ([arXiv:1512.06148](https://arxiv.org/abs/1512.06148))



high precision
near detector complex

Wide band, high purity ν_μ beam with peak flux at 2.5 GeV operating at ~ 1.2 MW and upgradeable

“Conceptual Design Report Volume 4: The DUNE Detectors at LBNF” ([arXiv:1601.02984](https://arxiv.org/abs/1601.02984))

- four identical cryostats deep underground
- staged approach to four independent 10 kt LAr detector modules
- Single-phase and double-phase readout under consideration

LBNF/DUNE Critical Decision Milestones

- **LBNF/DUNE held successful CD-1 Refresh Review July 14-16, 2015, at Fermilab**
 - Approved by ESAAB and signed by Lyn Orr on Nov. 5, 2015
- **LBNF CD-3a (initial far-site construction) Review conducted Dec. 2-4, 2015**
 - Office of Science (SC) Management approval decision anticipated in March 2016

CD-3a approval triggers construction of far site facility

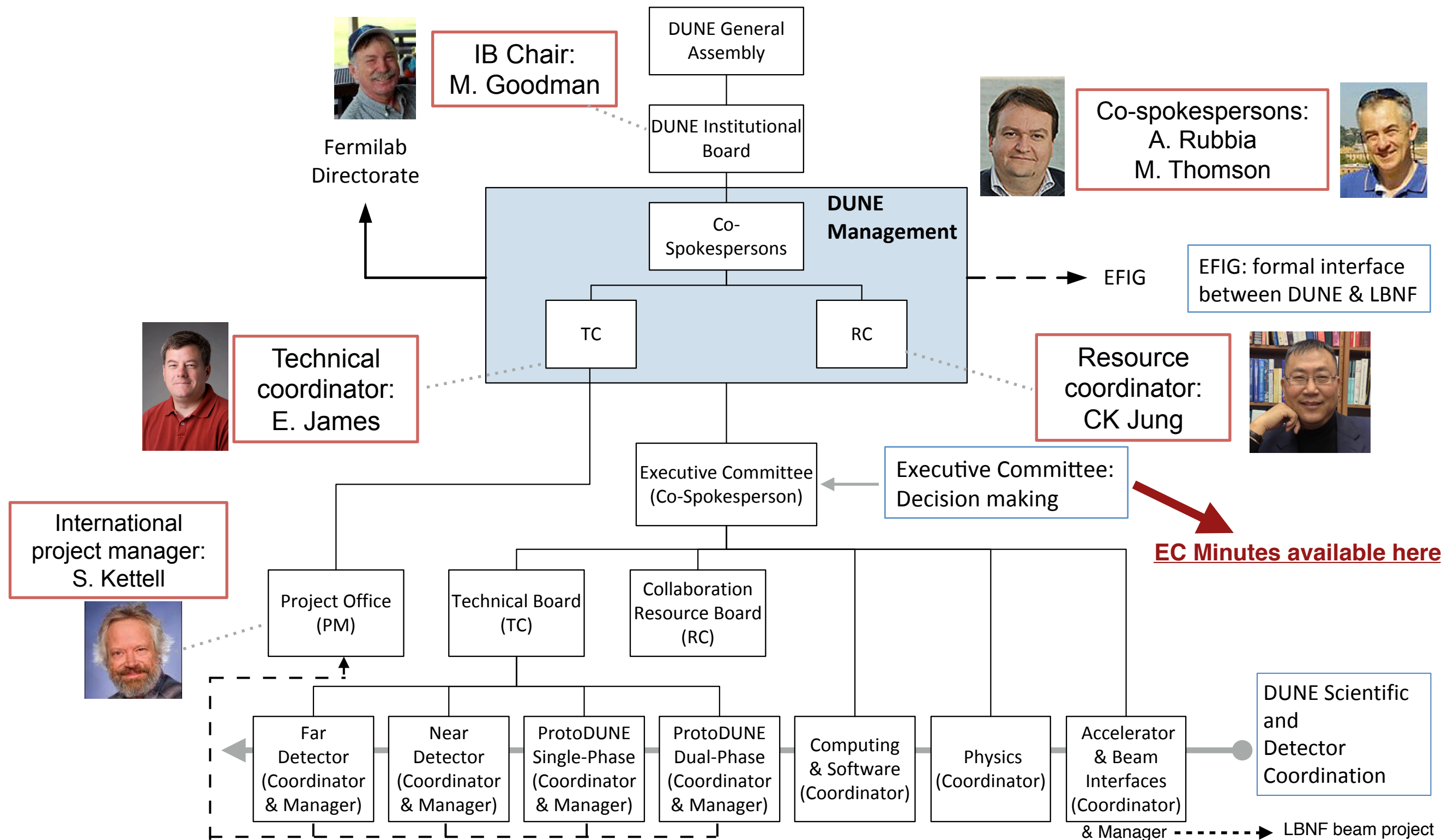
- **CD-3b (near site preparation) Review currently anticipated in early 2018**
- **CD-2 (baseline) and CD-3c (construction start) Review anticipated in 2019**
 - Cryostat #1 installation start in Q3/2020, TPC #1 installation start in **Q2/2022**, Detectors #1, 2 commissioning by **Q1/2026**, beam completed in **Q4/2026**
- **Proton Improvement Plan PIP-II is a separate project from LBNF/DUNE**
 - PIP-II will allow >1 MW beams on target for LBNF/DUNE - R&D on multi-MW neutrino target and focusing system proceeding in parallel within LBNF/DUNE

Progress in the DUNE organisation

- Since the formation of the Collaboration in April 2015, the proper organisation of the large DUNE Collaboration has been a high priority.
- **PAC Comment in June 2015 :** *“In the space of 3 months, collaboration leadership has been put in place, key strategic decisions have been taken, an exciting neutrino CP violation program that well exceeds the requirements of the P5 report and a complete and comprehensive CDR have been developed, and a credible cost and schedule laid out.”*
- While physics exploitation of DUNE can be seen as “far in the future”, the program requires significant engagement of a growing fraction of the Collaboration now.
- **PAC Comment in June 2015 :** *“Key near-term milestones coming up are CD-1R in July and CD-3a (LBNF). However, there is still a lot of work to do, including, in the near term, filling out the key management positions in the LBNF and DUNE projects, establishing the working groups and coordinators for DUNE, and launching the three task force groups to look at the Far Detector (FD) development plan, Near Detector (ND) requirements and concept development, and beamline optimization.”*
- We have continued to make progress in these areas.

The DUNE Management Organisation

The top-level management structure defined in the Collaboration Governance Document and approved by the DUNE Institution Board and **has been in place and functioning since April 2015.**



The Collaboration Resource Board

- Chaired by the **DUNE Resource Coordinator (RC)**
- Deals with all matters related to collaboration resources (financial, personnel, etc.) such as contributions to project common funds and division of project responsibilities among the collaborating institutions.
- **First meeting held in Nov 2015 - next on February 3rd 2016.**
- **Presently focusing on updating DUNE Matrix and preparing a DUNE Human Resource Survey at the institutional level.**
- [Next RRB meeting tentatively scheduled for May 2016.]

Country/FA	CRB Member	Country/FA	CRB Member
Armenia	N/A	Japan	Takuya Hasegawa
Belgium	Diego Aristizabal	Madagascar	Laza Rakotondravohitra
Brazil-FAPESP	Ernesto Kemp	Mexico	Alfredo Aranda
Brazil-MCTI/RENAFAE	Ricardo Avelino Gomes	Netherlands	Patrick Decowski
Bulgaria	N/A	Peru	Alberto Gago Medina
Canada	Scott Menary	Poland	Robert Sulej
CERN	Marzio Nessi	Romania	Bogdan Mitrica
Colombia	Mario Andres Acero Ortega	Russia	N/A
Czech Republic	Filip Jediny	Spain	Ines Gil Botella
France-CEA	Marco Zito	Switzerland	Antonio Ereditato
France-IN2P3	Dario Autiero	Turkey	Fatih Bay
Germany	N/A	UK	Alfons Weber
India	empty	Ukraine	Vladimir Aushev
Iran	N/A	USA-NSF	Edward Blucher
Italy	Sergio Bertolucci (TBC)	USA-DOE-U	Marvin Marshak
		USA-DOE-NL	Bonnie Fleming

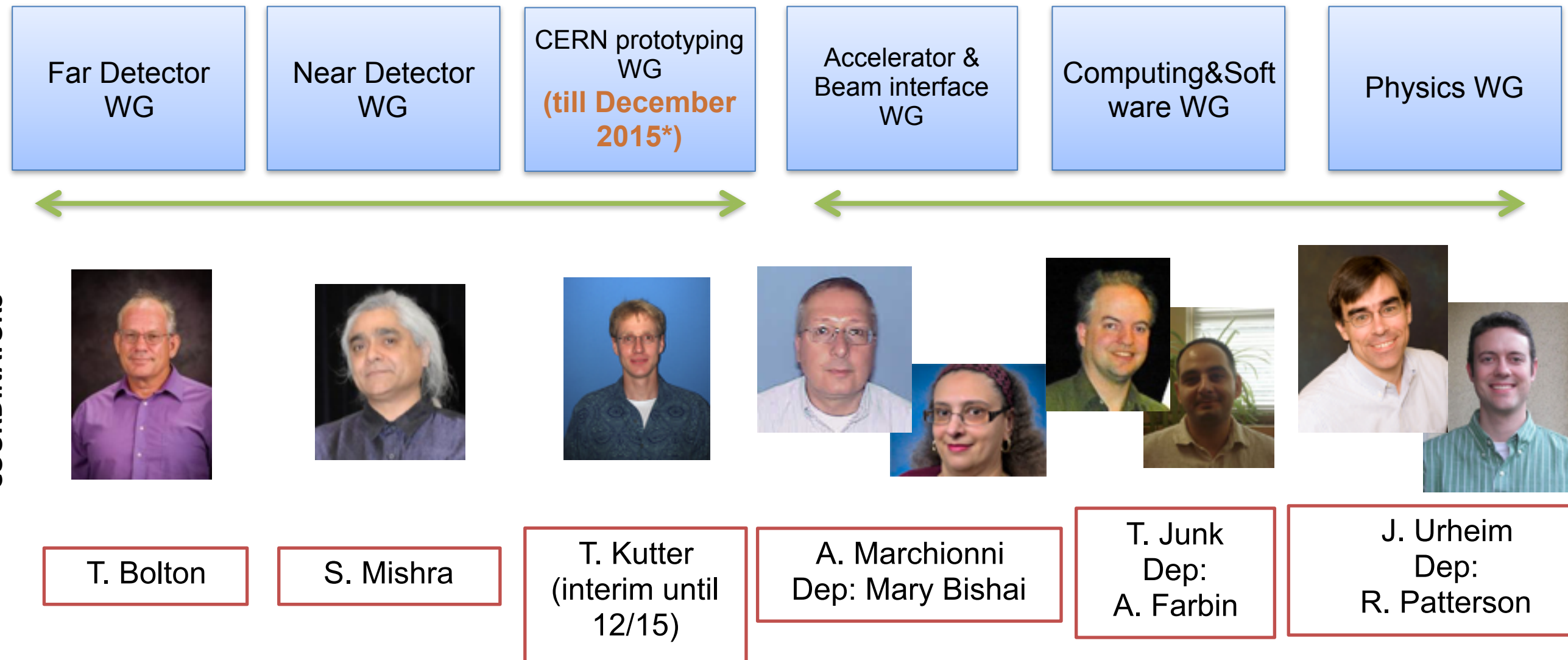
Majority of CRB members now in place

[Greece, Finland very recently joined and still need to be included]

} 3 US CRB members

DUNE Coordination Team

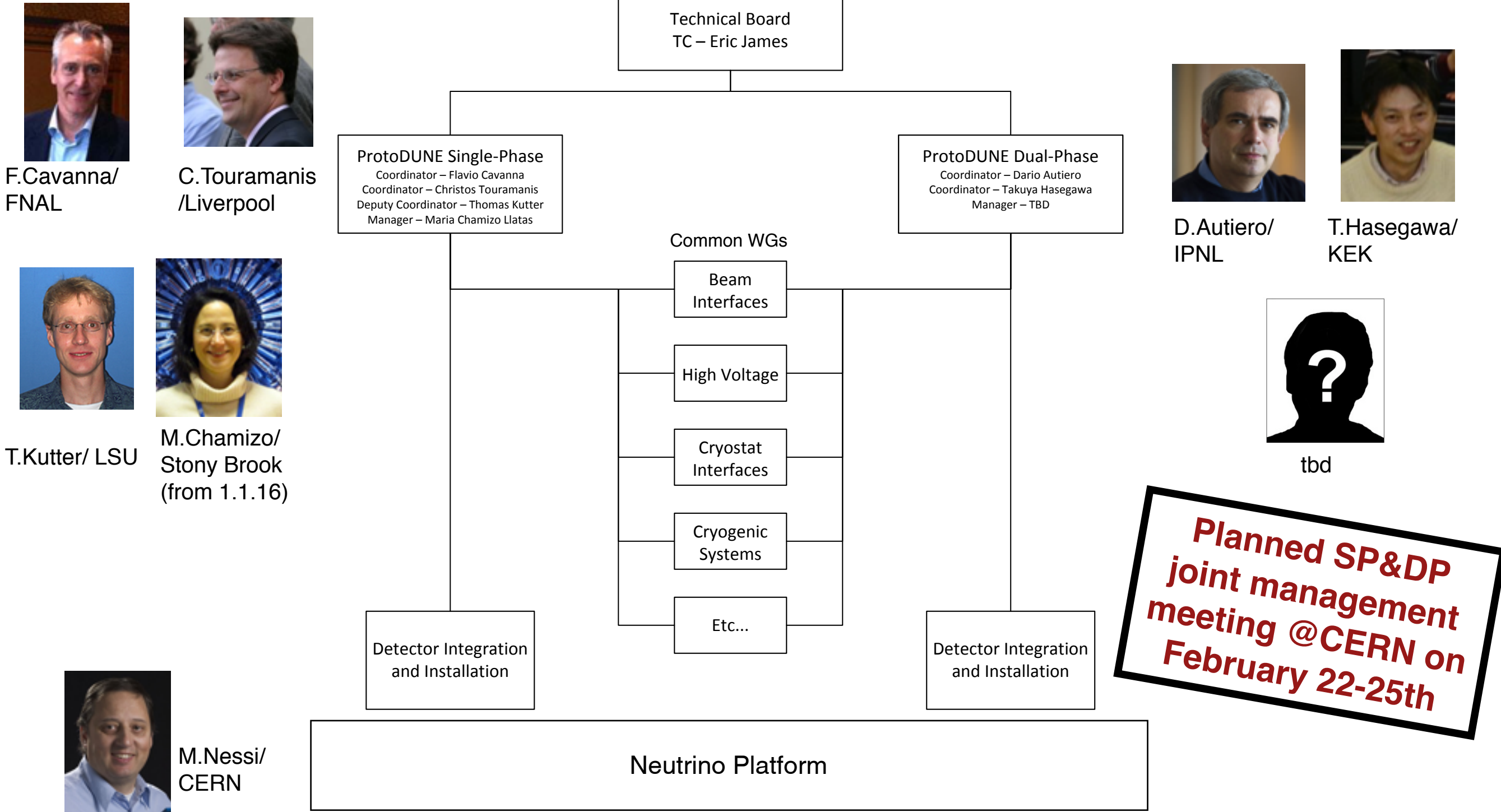
Since September 2015 all coordinators are in place
Role: responsible for coordination of DUNE working groups



- In December 2015 following approval of the single phase protoDUNE by CERN, the DUNE prototyping working group managed interim by Th.Kutter has been expanded (see next slide).

CERN protoDUNE management

The **DUNE prototypes form an integral part of the DUNE collaboration** and consequently their Management is embedded in the DUNE Management and organization, with a local coordination for each of the single & dual phase protoDUNE prototypes.



DUNE Task Forces

- In addition to WGs, we have set up three “Task Forces” to address strategically important issues:
 - Task force leadership reports the DUNE executive committee
 - Focus on collaboration goals/open questions for CD-2
 - Activities cross boundaries of various working groups
 - For example physics, reconstruction software and far detector WGs
 - **Limited duration: deliver report in 18 months → ≈Summer 2017**

TF 1: Near Detector Optimiz.
Steve Brice
Deputy: Dan Cherdak
Deputy: Kendall Mahn



TF 2: Far Detector Optimiz.
Lisa Whitehead
Deputy: Andy Blake
Deputy: Slavic Galymov



TF 3: Beam Optimiz.
Alfons Weber
Deputy: Laura Fields



Very critical efforts

- ★ End-to-end simulation of Near Detector design and analysis
- ★ Evaluate impact on far detector systematics
- ★ Evaluate benefits of alternative designs

- ★ End-to-end simulation and full reconstruction of far detector
- ★ Validation (optimization) of design parameters (e.g. wire spacing)
- ★ Update physics sensitivities with full simulation for CD-2

- ★ Further develop physics-driven optimization of the beam line
- ★ Identify options for improvements and present a first-order cost-benefit analysis

DUNE regular meetings

- Weekly, Bi-weekly and or Monthly high-level meetings fully in place and working well, alternating between “detector weeks” & “physics weeks”
- Effort to select time-slots that are practical for members located in different timezones around the world. Predefined favoured fixed slots (e.g. 10am-12pm CT) leaving time outside them.
- Fully integrated “indico” system with automatic calendar generation, easily accessible from the “DUNE @ Work” web page ([DUNE @ work link](#))

DUNE (events overview)

[Go back to category page](#)

<< < Friday 01 January 2016 – Sunday 31 January 2016 > >>

January, 2016

Today

Mon Tue Wed Thu Fri Sat Sun

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Select date

Display options:

Period: month

Detail level: agenda

Apply

Monday	Tuesday	Wednesday	Thursday	Friday
				1
4	5	6	7	8
08:00 DUNE Project Management Meeting (Kettell, Steve)	10:00 LBL Bi-weekly Meeting	10:00 35 Ton Phase 2 Technical/Run Coord. Weekly Meeting (Readytalk 5379204: WH 3rd floor NW (Theory Conf))	10:00 Accelerator and Beam Interface Group (Fermilab: Hornet's Nest (WH800))	09:00 EC meeting
10:00 FD Simulation and Reconstruction Bi-Weekly (Yang, Tingjun)			15:00 DUNE Far Detector Leaders January 7 2016	09:30 35ton Sim/Reco (PPD Nus room 12th floor Xover)
11	12	13	14	15
10:00 DAQ Meeting (Dr. MARTEAU, Jacques; Graham, Mathew; Karagiorgi, Georgia; Barr, Giles)	08:00 DUNE Collaboration Meeting - UTA (University of Texas, Arlington (UTA):)	09:00 DUNE Collaboration Meeting - UTA (University of Texas, Arlington (UTA):)	08:00 DUNE Collaboration Meeting - UTA (University of Texas, Arlington (UTA):)	09:00 DUNE Collaboration Meeting - UTA (University of Texas, Arlington (UTA):)
		10:00 35 Ton Phase 2 Technical/Run Coord. Weekly Meeting (Readytalk 5379204: WH 3rd floor NW (Theory Conf))	08:00 Technical Board Meeting	
		16:00 EFIG Meeting 13 January 2016 (UTA: NH112)	12:30 DUNE IB meeting at the January 2016 Arlington Meeting (UTA Arlington Texas: tbd)	
18	19	20	21	22
	10:30 DUNE PMG	10:00 35 Ton Phase 2 Technical/Run Coord. ...		

DUNE - Primary Science Programme

Focus on fundamental open questions in particle physics and astro-particle physics – aim for discoveries:

1. Long baseline neutrino oscillations

- Precise measurement of the L/E behaviour for neutrinos and anti-neutrinos
- **High discovery potential** for **leptonic CPV** and **guaranteed determination of θ_{23}** test of 3- ν flavour oscillation paradigm; determine the sector of Θ_{23}
- Complete knowledge of PMNS matrix by precisely determining all parameters including CP-phase. Fundamental parameters of the SM \rightarrow CKM and PMNS matrices to shed light on the **flavour problem**.

Physics WGs to further explore and update the physics scope, e.g. NSI, BSM, ...

Physics milestone	Exposure kt · MW · year (reference beam)	Exposure kt · MW · year (optimized beam)
1° θ_{23} resolution ($\theta_{23} = 42^\circ$)	70	45
CPV at 3 σ ($\delta_{CP} = +\pi/2$)	70	60
CPV at 3 σ ($\delta_{CP} = -\pi/2$)	160	100
CPV at 5 σ ($\delta_{CP} = +\pi/2$)	280	210
MH at 5 σ (worst point)	400	230
10° resolution ($\delta_{CP} = 0$)	450	290
CPV at 5 σ ($\delta_{CP} = -\pi/2$)	525	320
CPV at 5 σ 50% of δ_{CP}	810	550
Reactor θ_{13} resolution ($\sin^2 2\theta_{13} = 0.084 \pm 0.003$)	1200	850
CPV at 3 σ 75% of δ_{CP}	1320	850

Opportunities for early discoveries!

DUNE - Primary Science Programme

2. Nucleon Decay

- EW+QCD are all local-gauge QFT with similar structure → GUT ? many hints exist in favour (high energy behaviour of couplings; $Q_e = -Q_p$, neutrino masses, ...) but the **missing link** is the **direct observation of a nucleon decay**. Its discovery would be monumental and measurements of branching ratios inform GUT models (SUSY, non-SUSY)

E.g. sensitivity for
200 kton×year
exposure

Mode	Lifetime (90%C.L.)
$p \rightarrow \nu K^+$	$> 3 \times 10^{34}$ yrs
$p \rightarrow e^+ \gamma, p \rightarrow \mu^+ \gamma$	$> 3 \times 10^{34}$ yrs
$p \rightarrow \mu^- \pi^+ K^+$	$> 3 \times 10^{34}$ yrs
$n \rightarrow e^- K^+$	$> 3 \times 10^{34}$ yrs
$p \rightarrow \mu^+ K^0, p \rightarrow e^+ K^0$	$> 1 \times 10^{34}$ yrs
$p \rightarrow e^+ \pi^0$	$> 1 \times 10^{34}$ yrs
$p \rightarrow \mu^+ \pi^0$	$> 0.8 \times 10^{34}$ yrs
$n \rightarrow e^+ \pi^-$	$> 0.8 \times 10^{34}$ yrs

Physics WGs to
further explore and
update the physics
scope (e.g. n - n bar)

3. Neutrino astrophysics, including supernova detection

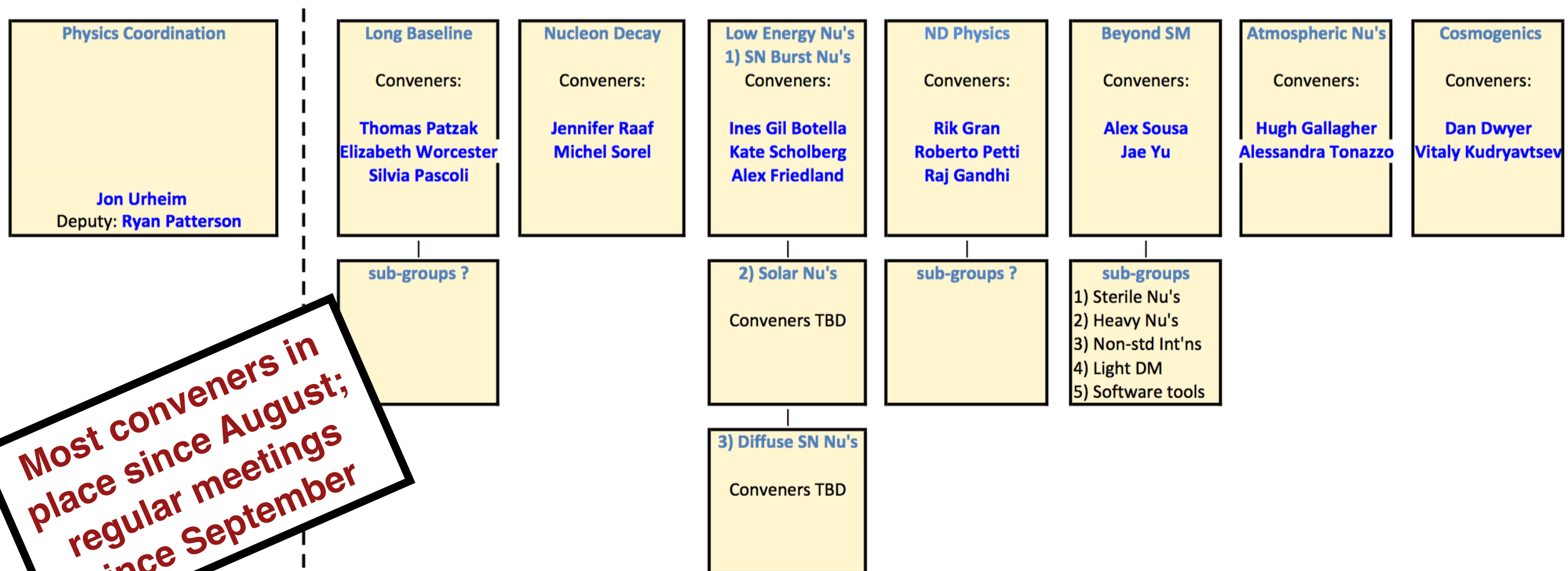
- SN burst to verify models of stars' explosions; but also neutrino physics (e.g. flux from cooling process is very sensitive to matter effects, sterile neutrinos, anomalous magnetic moment, etc...)

Progress in assessing physics reach

- The DUNE physics program presented in the CDR Vol 2 has been essentially based on (conservative) however parameterised responses of the detectors. While providing good feedback on the physics potential of DUNE, a better understanding of the physics channels is required for the TDR towards CD2 review.
- Furthermore, PAC underlined
 - *“A full capability for end-to-end simulation and reconstruction of events, extending from neutrino flux to final statistical analysis, is urgently needed. Such an effort would go well beyond the existing GLoBES performance estimates in terms of reliability and detailed performance assessment. There has been a long-standing need for such a tool for the LAr technology and it is essential for a robust understanding of physics reach and design optimization of both the FD and ND. Since SBN LAr detectors are also developing fully automated event reconstruction, close connections should be maintained to advance the state-of-the-art as quickly as possible driven by TPC data.”*

DUNE Physics WG organisation

- Seven sub-WGs focused on primary but also secondary physics program
 - LBL, NDK, SNB/lowE, ND physics, BSM, ATM, Cosmogenics
- Also engage **the theory/phenomenology community** (conveners, dedicated workshops, ...)
 - e.g. 11/2015 Supernova Neutrino workshop at SLAC
 - planning an atmospheric neutrino workshop



DUNE Physics WG + TFs

- Significant progress in all seven WGs (LBP, NDK, SNB/lowE, Cosmo, ATM, BSM) aided by focused efforts within the ND/FD/BO Task Forces
- One urgent goal is indeed getting **robust understanding of physics reach** and performing **detector design optimization** of the **FD SP/DP** and **ND FGT/LAr/HPGAr**.
 - * Develop the full capability for end-to-end simulation and reconstruction of events in conjunction with FD/ND TF and SW/C WGs to reliably estimate signal efficiencies and backgrounds.
 - * “Aided/fake reconstruction” codes being implemented but required efforts are significant (this is an area where more manpower is needed)
 - * Develop “fully automated reconstruction” of NDs and FDs – mid term drivers are protoDUNEs data analysis. Work connected to SBN program.

WG & TF have now developed clear plans with detailed milestones. Generally speaking tasks are well staffed. But no surprise, there are gaps.

Engaging manpower for WG&TF (I)

- PAC commented**

- “The PAC sees a potential issue with growing the number of active people in the collaboration. The efforts to establish Task Forces and WGs are very important as a way of engaging collaboration members. The collaboration must continue to grow, either naturally as the project gains visibility and momentum, or through dedicated efforts to target specific groups/nations.”*

➔ **We have performed a Resource Planning Exercise of TF & physics WG**

- Collected tasks list, estimated manpower requirements (FTE)

- Standard format to input data - e.g. feedback from FD TF:

WG	Task Number (to be filled in later)	Task (Description)	Priority (High, Medium, Low)	Desired Start Date (e.g. Q1 2016)	Estimated Duration (Months)	FTE %	Type Sci or Eng	Name (or X)
FD Sim/Reco		Implement and validate dual-phase simulation		Q1 2016	4	0.5	S	Slavic, Elisabetta
FD Sim/Reco		Improvements in photon detector simulation ("photon library optimization")		Q1 2016	4	0.5	S	X
FD Sim/Reco +LBL		Analysis ntuple		Q1 2016	12	1	S	Tingjun Yang/X
FD Sim/Reco		Single-phase geometries for FD TF optimization studies (probably complete)		Q4 2015	1	0.25	S	Tyler(?)
FD Sim/Reco		Dual-phase geometries for FD TF optimization studies		Q2 2016	1	0.25	S	Slavic, Elisabetta
FD Sim/Reco (+LBL?)		Electron neutrino ID ("nu_e CC identification")		Q4 2015	6	1	S	Tingjun/Mike
FD Sim/Reco		Large scale production of samples for FD TF optimization studies		Q1 2016	6	0.25	S	X
FD Performance		Choice of highest priority optimization studies for FD TF		Q4 2015	2	0.1	S	FD WGs
Supernova/Low-E		Implement and validate supernova neutrinos in LArSoft ("Simple SN event gener		Q1 2016	1	0.1	S	Scholberg/Sinev
Supernova/Low-E		Establish performance parameters to consider in FD optimization studies		Q1 2016	1	0.1	S	Kate/Ines
Supernova/Low-E		Preliminary FD TF optimization studies ("Physics studies with basic sim/recon")		Q2 2016	6	0.5	S	X
Supernova/Low-E		Final FD TF optimization studies ("Physics studies with basic sim/recon")		Q3 2016	6	0.5	S	X
Supernova/Low-E		High-level reconstruction ("Preliminary recon/tagging")		Q1 2016	6	0.5	S	X
Nucleon Decay		Implement and validate nucleon decay sources in LArSoft ("Re-evaluate GENIE/L		Q1 2016	3	0.5	S	Jeremy Hewes
Nucleon Decay		Establish performance parameters to consider in FD optimization studies		Q1 2016	1	0.1	S	Jen/Michel
Nucleon Decay		Preliminary FD TF optimization studies ("Preliminary signal selection & backgrou		Q3 2016	6	0.5	S	X
Nucleon Decay		Final detector FD TF optimization studies ("Preliminary signal selection & backgr		Q4 2016	6	0.5	S	X
Nucleon Decay		High-level reconstruction (Validate high-level reconstruction algorithms")		Q1 2016	3	0.5	S	X
Atmospheric Nus		Implement and validate atmospheric neutrinos in LArSoft ("Testing and improvi		Q1 2016	2	0.5	S	X
Atmospheric Nus		Establish performance parameters to consider in FD optimization studies		Q1 2016	1	0.1	S	Hugh/Alessandra
Atmospheric Nus		Preliminary FD TF optimization studies ("Updating / re-evaluation of detector pe		Q2 2016	6	0.3	S	X
Atmospheric Nus		Final FD TF optimization studies ("Updating / re-evaluation of detector performa		Q3 2016	6	0.3	S	X
Atmospheric Nus		High-level reconstruction (?)		Q1 2016	6	0.5	S	X
Long-baseline		Establish performance parameters to consider in FD optimization studies		Q1 2016	1	0.1	S	Elizabeth/Thomas
Long-baseline		Preliminary FD TF optimization studies ("Evaluate sensitivity for ND/FD TF studie		Q2 2016	6	1	S	X
Long-baseline		Final FD TF optimization studies ("Evaluate sensitivity for ND/FD TF studies")		Q3 2016	6	1	S	X
Long-baseline (+FD Sim/Reco?)		Electron neutrino ID ("AnaTree Initial analysis")		Q1 2016	6	1	S	Elizabeth Worcester/X
Long-baseline		Develop oscillation analysis ("DUNE fitter")		Q1 2016	6	1	S	Dan Cherdack/X
Long-baseline		Preliminary MC-based sensitivity ("Evaluate sensitivity for ND/FD TF studies")		Q2 2016	6	1	S	X
Long-baseline		Demonstrate improvement in sensitivity ("Evaluate sensitivity for ND/FD TF stu		Q3 2016	6	1	S	X

+ many other tables from all other TF+WGs

Estimates manpower for WG&TF

- **Still preliminary data**
 - Different groups at different levels of maturity
 - **Overall positive but some gaps that need to be resolved in near future**
 - TF are generally well staffed and have clear milestones
 - Largest gap presently in physics WG in some specific areas such as e.g. atmospheric
- ➔ Map and cross-ref with Collaboration Manpower Survey (via the CRB/IB)

ND TF summary	
# of milestones/tasks	127
FTE-years required	4.3
FTE-years available	4.3
Shortfall	0
FD TF summary	
# of milestones/tasks	29
FTE-years required	7.2
FTE-years available	2.9
Shortfall	4.3
BO TF summary	
# of milestones/tasks	14
FTE-years required	10
FTE-years available	2.3
Shortfall	0.5

Physics WGs summary	
# of milestones/tasks	66
FTE-years required	31.4
FTE-years available	19
Shortfall	12.4



Physics WG	Required	In place	Fraction
LBL	18.5	14.5	78 %
Atmospheric	1.3	0	0 %
NDK	2.0	0.7	35 %
Low Energy/SNB	3.0	1.7	57 %
Cosmogenics	6.6	2.2	33 %

Progress on the ND complex

- **PAC commented**

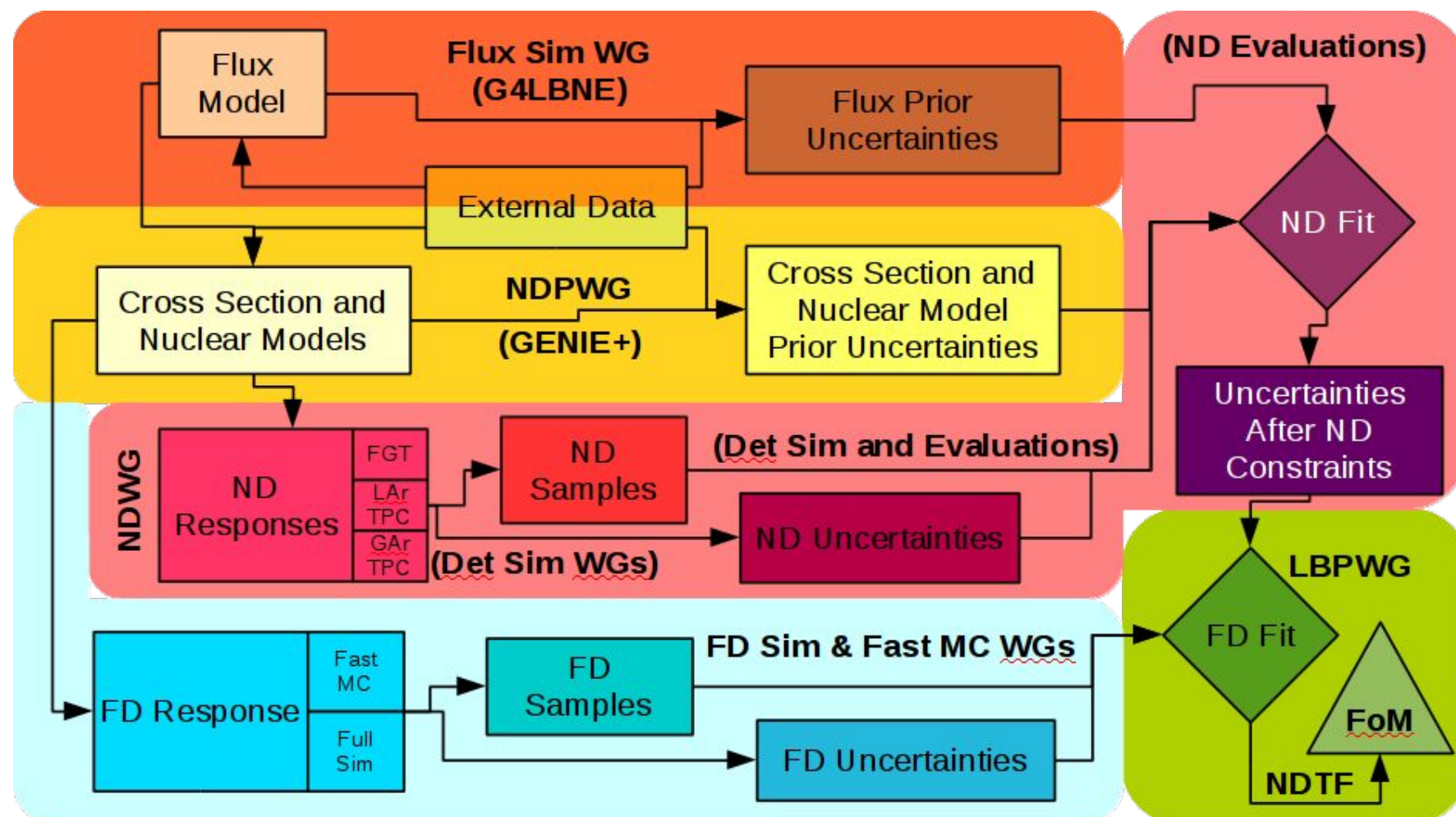
- “Near detector (or ND complex) design and impact. **The PAC encourages the broad engagement of the DUNE collaboration in the process of understanding the requirements and conceptual design of the ND.** In the next 12-18 months, the ND task force should also develop a strategy for incorporating additional knowledge on neutrino events, their reconstruction, and relevant neutrino cross sections from LAr and neutrino cross section efforts coming online. In this regard, more work should be done to evaluate the importance and impact on systematic error improvements by planned programs such as CAPTAIN-MINERvA, even though initially the CP violation program will be statistics limited.”

➔ **Our efforts progress on two coordinated and complementary fronts:**

- ★ (1) The **ND TF** has made important progress towards an end-to-end simulation of Near Detector design and analysis, evaluate impact on far detector systematics, and evaluate benefits of alternative ND designs (*developing the “machinery” - see next slide*).
- ★ (2) the **ND physics working group** guides the physics basis for choosing one or a combination of near detector technologies or optimized design, while assessing how a highly capable near detector enables a rich physics measurement program in addition to the oscillation results a generational advance in neutrino interaction measurements.
 - This group also outlines the relevant “physics channels” and/or “analyses” such as:
 - the absolute flux constraint from neutrino-electron elastic scattering,
 - relative flux measurement with the “low-nu” method,
 - detector capabilities to measure specific exclusive cross-section channel (e.g. Δ resonance)
 - keeping track of the evolving neutrino interaction cross section landscape.

Highlights on progress of ND TF (TF1)

- **Established comprehensive simulation and analysis path**
 - Based on extensive expertise on currently running LBL exp (T2K, NOvA, ...)
 - Includes flux errors, cross-section uncertainties, (preliminary) detector uncertainties, near/far extrapolation
 - Three ND detector options: **FGT, LAr TPC, HP GAr TPC**
- **The 1st run through of the entire chain of processing is underway and should complete by end Jan 16 (meeting 1st major milestone is on schedule)**
 - Aimed at proving the machinery → physics studies will start promptly afterwards



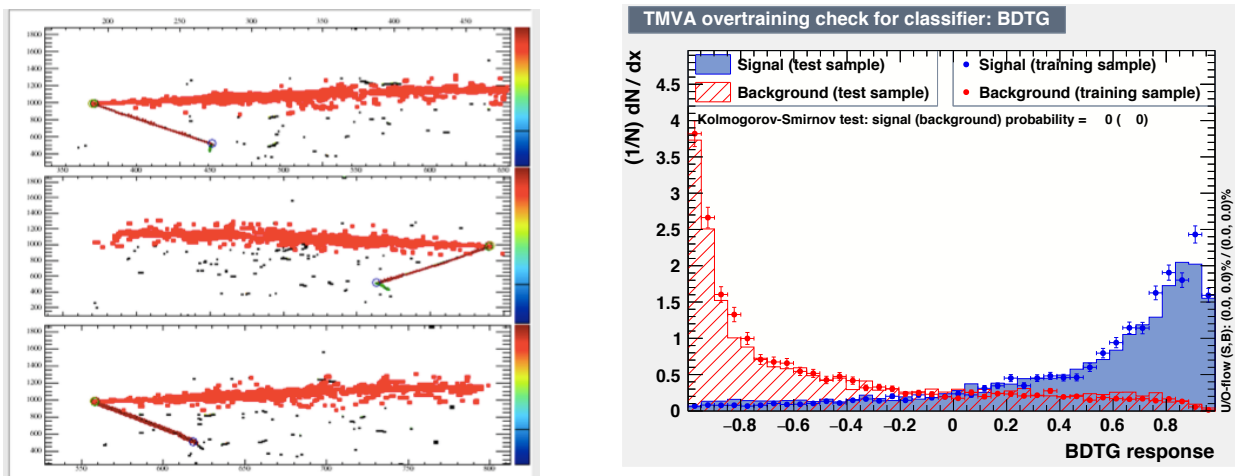
Highlights on progress of FD TF (TF2)

- **Significant progress in conjunction with S&C Simu&Reco group**
 - Implementation of event generators for supernova neutrinos (SNNueAr40CCGen & MARLEY), for proton decay (within GENIE), and high energy CR muons (MUSUN)
 - Implementation of DUNE 10kton dual-phase detector simulation in LArSoft
 - Implementation of geometries for FD optimisation studies (wire spacing, wire angle, ...)
- **Production of Monte-Carlo Challenge**
 - MCC5.0 ready for analysis (single particles, beam neutrinos, SN neutrinos, various detector configurations)

First ν_e Event Selection

TY

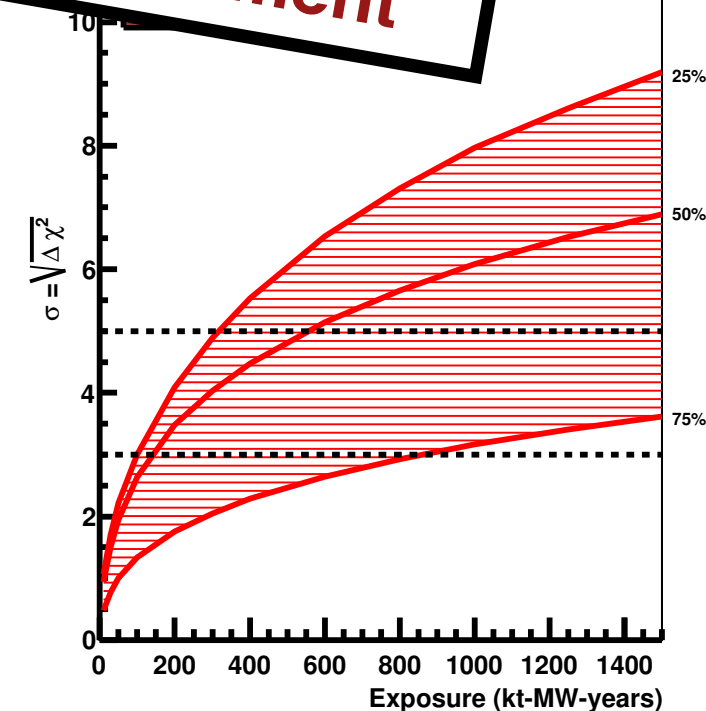
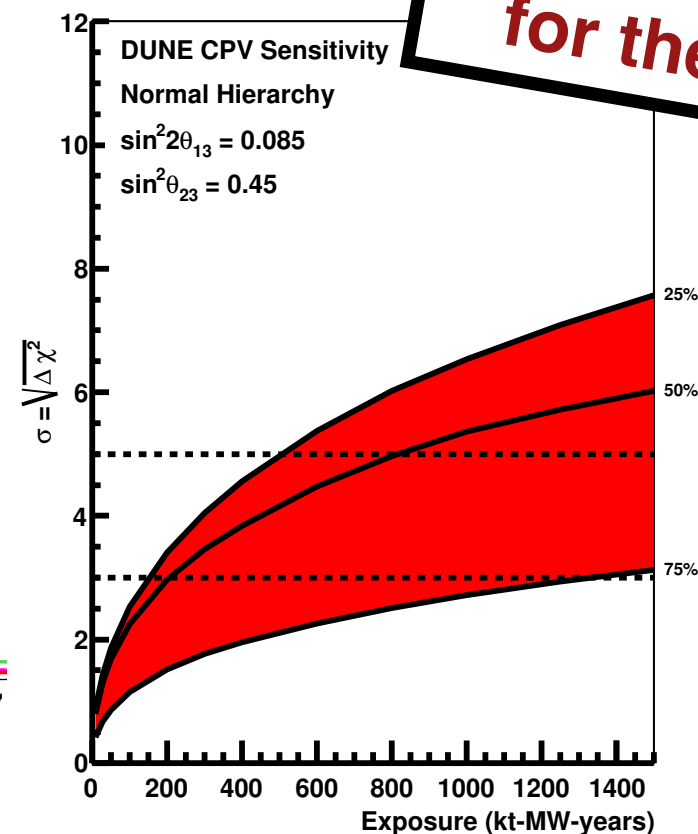
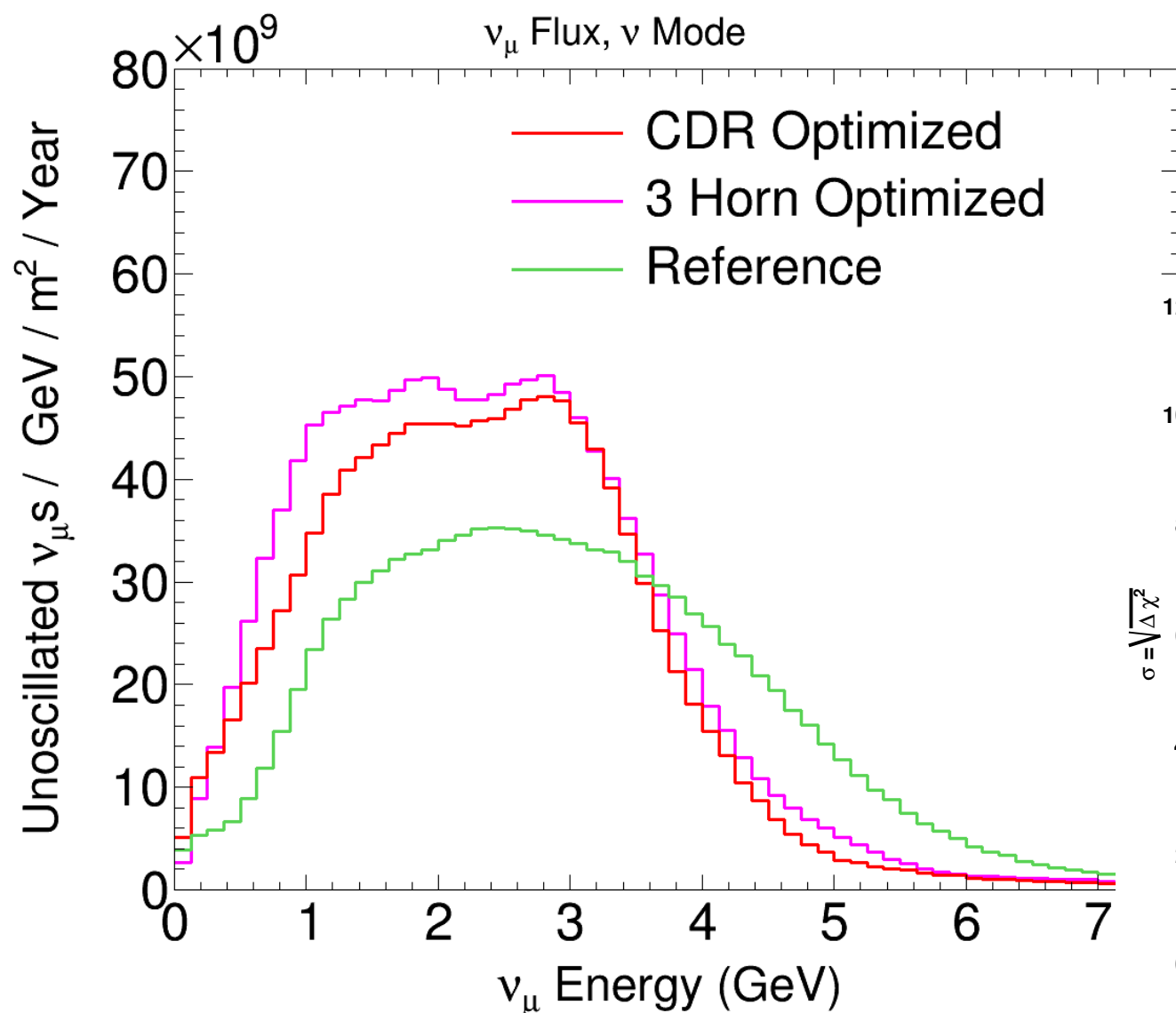
- ν_e event selection performed on simulated neutrino interactions w/ realistic flux.
- Fully automated reconstruction algorithms in LArSoft (Pandora+EMShower)
- Boosted Decision Tree event selection using 24 input variables
- First pass achieves significant (>80%) reduction for both NC and CC background for 80% signal selection efficiency
 - Did not include Dorota's dE/dx and gap information, improvements expected.



- **Preliminary studies of reconstruction performance**
 - Shower reconstruction, improvements in reconstruction algorithms (Pandora, PMA, WireCell)
 - Handling of wrapped wire configuration for single phase FD
 - Deep Neural Network: machine learning
- **Preliminary event selection based on reconstructed variables**

Highlights on progress of BO TF (TF3)-I

- Beam characteristics (energy profile) have a direct impact on the physics reach for a given amount of protons-on-target.
 - Significant effort to optimise the beam focusing system for given physics channels (e.g. CPV sensitivity)
- Current state of the art yields double flux at the 2nd maximum !



Beam characteristics (and near detector complex) are crucial for the experiment

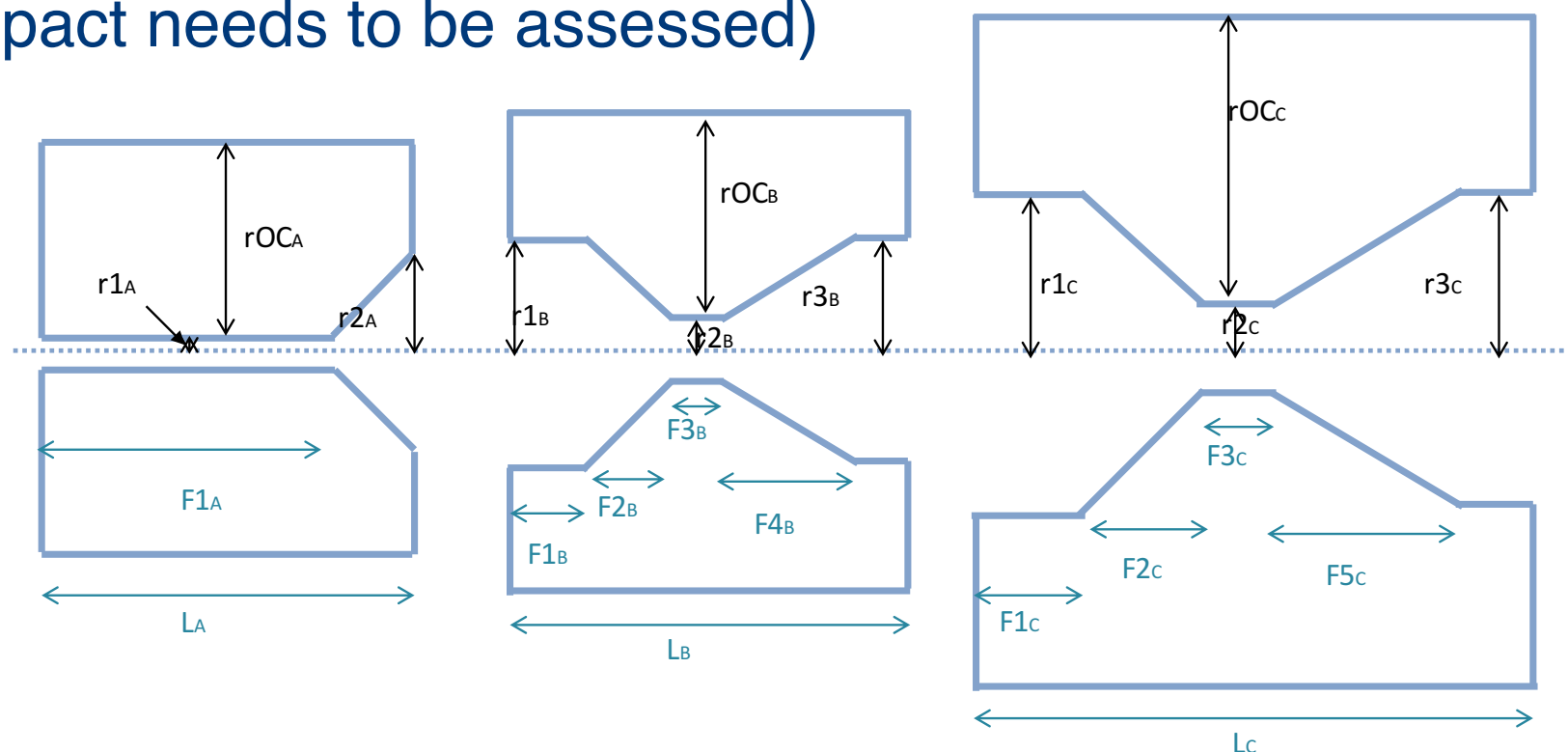
Highlights on progress of BO TF (TF3)-II

- **What we know already:**

- Substantially improved beam optics fits in current target hall
- A 3-horns system with currents around 300kA is strongly favoured
- A long (2m) target is strongly preferred
- The current design of the hadron absorber is not optimal for physics (muon monitoring) and a longer target would change the requirements on the absorber

- **Open questions:**

- The preferred material of the target
- Full impact on CF and beam line of new focusing system
- Cooling fluid in target chase (reference is air; strong preference to go to N2 or He but full impact needs to be assessed)



A coordinated effort between LBNF&DUNE

- **EFIG (Experimental Facility Interface Group) started discussions towards optimisation and finalisation of NSCF and beam for DUNE**
 - Roles and responsibilities of LBNF and DUNE well defined
 - Includes necessary engineering input to optimised design
- **Beam line full preliminary design ready by CD-2**

ROLES
R= responsible/leader
S= support
I=inform

LBNF/DUNE beam line optimisation tasks

near term summary tasks	Task Force	Working Group	Beamline Project	EFIG
scientific requirements for beam		R	I	
coordinate support for beam from DUNE collaborators		R	I	
simulations of optimized beam	R	S	I	
engineering input to optimized beam components	I	I	R	
cost estimate of optimized beam components	I	I	R	
report on optimized beam	R	S	I	
conceptual engineering design of 1.2MW optimized target, horns, absorber	I	S	R	
cost/benefit analysis of alternate atmosphere in target chase	I	S	R	
decisions regarding alternates & options/changes to reference design		S	S	R

Progress in Software & Computing WG

- **Computing Model document has been drafted and will be internally reviewed by Collaboration**

- Understand the requirements of all detectors (35T, protos, ND, FD)
- CPU and data storage requirements
- Support simulation and reconstruction challenges for FD
- Short term (2016) : 35T & WA105 3x1x1 data taking and analysis
- Mid term: ProtoDUNES SP & DP requirements

- **E.g. WA105 total data volume estimates**

- **175M triggers**

- If stored in non-zero-skipped, lossless compression format (Huffman, factor 10 compression) → **2.4PB**

TABLE XIX: Requirements for particles and their momenta. The particle rate here is the rate within a spill, regardless of the spill length, slow extraction is assumed.

Type	Momentum [GeV/c]	Rate [kHz]	Total	Time est. [hrs]
Muon tracks				
$\mu^{+/-}$	0.8, 1.0, 1.5, 2.0, 5.0, 10.0, 20.0	0.1	$5 \times 10^6 \times 14$	200
Shower reconstruction				
$\pi^{+/-}$	0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 20.0	0.1	$5 \times 10^6 \times 14$	200
e	0.5, 0.7, 1.0, 2.0, 5.0, 10., 20.0	0.1	$5 \times 10^6 \times 7$	100

- Beam rate = 100Hz, **data flow = 15 GB/s**, installing 20 GB/s link from CERN EHN1 to IT computing centre
- Online computing to monitor data and 1PB local storage
- **Computing infrastructure not supported by the project but is essential to the overall success of the effort – DUNE aware of the issue.**

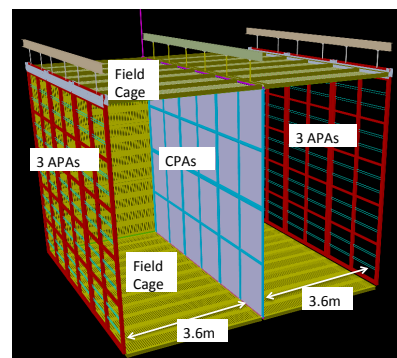
Far Detector Prototyping Program

- DUNE has well-developed plans for a series of detector prototypes that will provide input to the process leading to the final design(s) for the DUNE far detector modules.
- Crucial benefits of the prototyping program are:

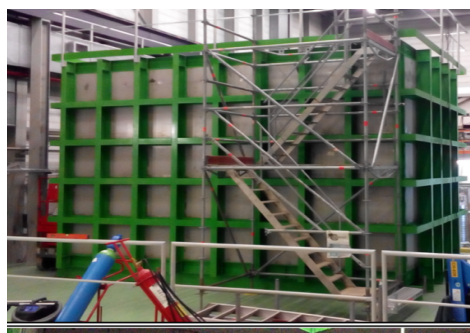
35T @ FNAL



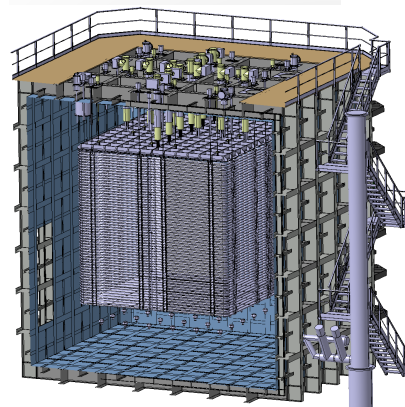
NP04 @ CERN



WA105 3x1x1 @ CERN



WA105 @ CERN



- *Mitigation of risks associated with current detector designs*
- *Establishment of construction facilities required for full-scale production of detector components*
- *Early detection of potential issues with construction methods and detector performance*
- *Provides required calibration of detector response to particle interactions in test beam*

- Critical path activities to follow the planned installation of the first and subsequent 10-kton far detectors at SURF in the early 2020's

Ongoing prototyping efforts

- **Single-phase : 35T @ FNAL**
 - Very significant and successful effort of integration in the last months
 - Significant developments in electronics/DAQ chain integration
 - Gas purge phase started; **LAr filling scheduled for January 2016**
 - Test of wrapped wires APA concept (resolution of ambiguities, charge collection, ...), cold electronics, noise, ZS, PDS, etc.
- **Dual-phase : 3x1x1m3 @ CERN**
 - First GTT membrane cryostat constructed and thoroughly tested (membrane leak rate, exoskeleton concept, tightness, etc...)
 - Detector integration starts in January 2016
 - **Cryogenic operation foreseen for September 2016**
 - First demonstration dual-phase performance at 10-ton scale

Getting ready for data taking and analysis. This will represent an important milestone for the Collaboration.

The protoDUNE initiatives

- **Timescale is critical to inform CD2 and aiming to collect physics data before LHC LS2**
- **Management is now in place (finally)**
 - New integrated and symmetric organisational structures for single- and dual-phase with highly-experienced coordination teams
 - New structure allows to take maximum advantage of the synergies between the two efforts and profit from earlier start of WA105 at CERN NP.
- **Technical organisation is in place**
 - Internal reviews e.g. cryostat internal review Dec 15, CFD review, etc...
 - feedback and actions discussed by DUNE Technical Board, then recommendations via TC to EC Board.
 - Engineering resources are critical for the timely success of the efforts (support from Labs & institutions is crucial)
- **Resources and institutional responsibilities**
 - **MoUs for WA105 & NP04 signed with CERN**
 - **Establishing a model for non-DOE funding and institutional responsibilities of single-phase protoDUNE is a major short-term goal.**
 - **Need dedicated teams stationed at CERN.**

CERN EHN1 extension integration

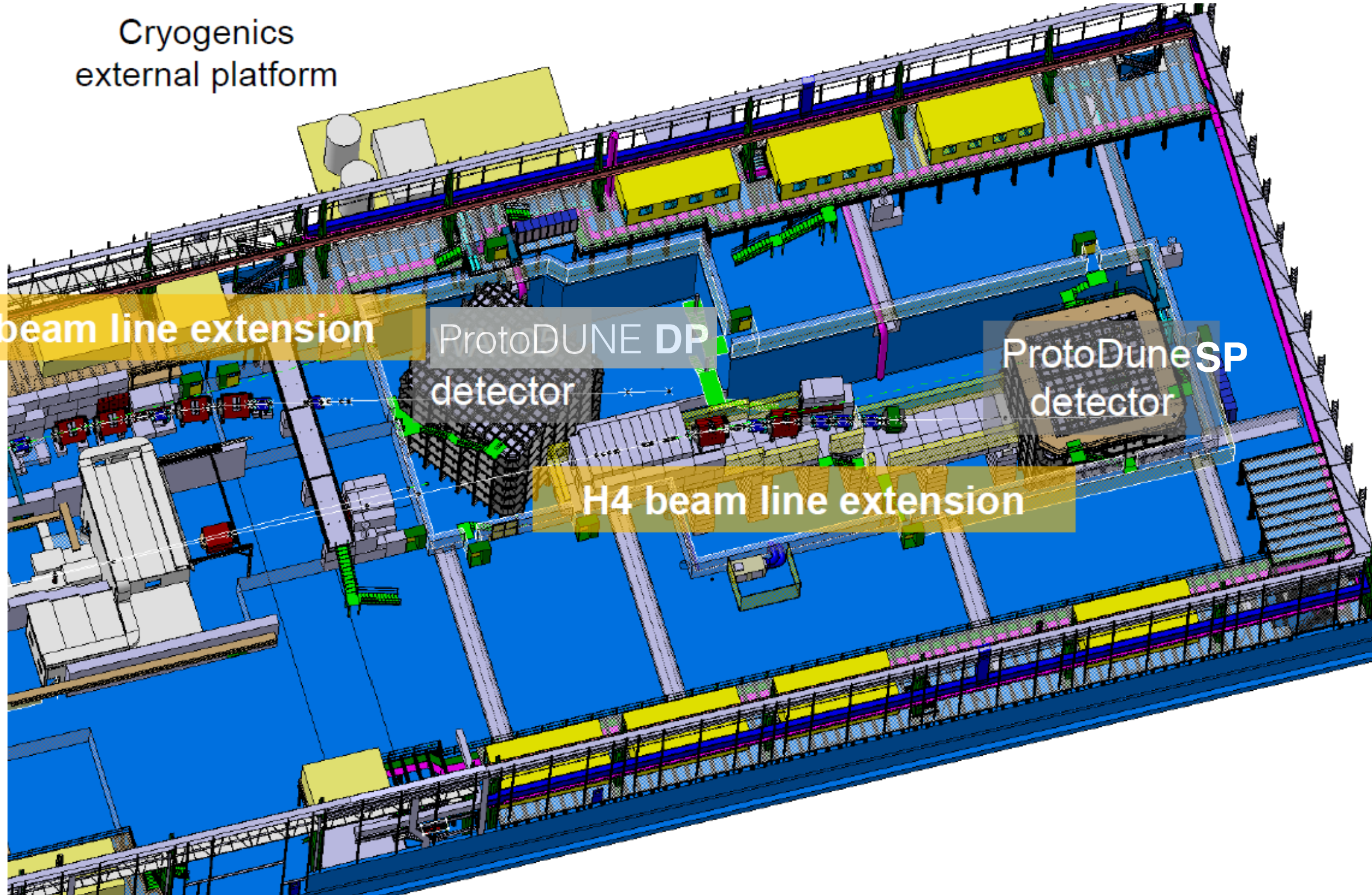
Cryogenics
external platform

H2 beam line extension

ProtoDUNE DP
detector

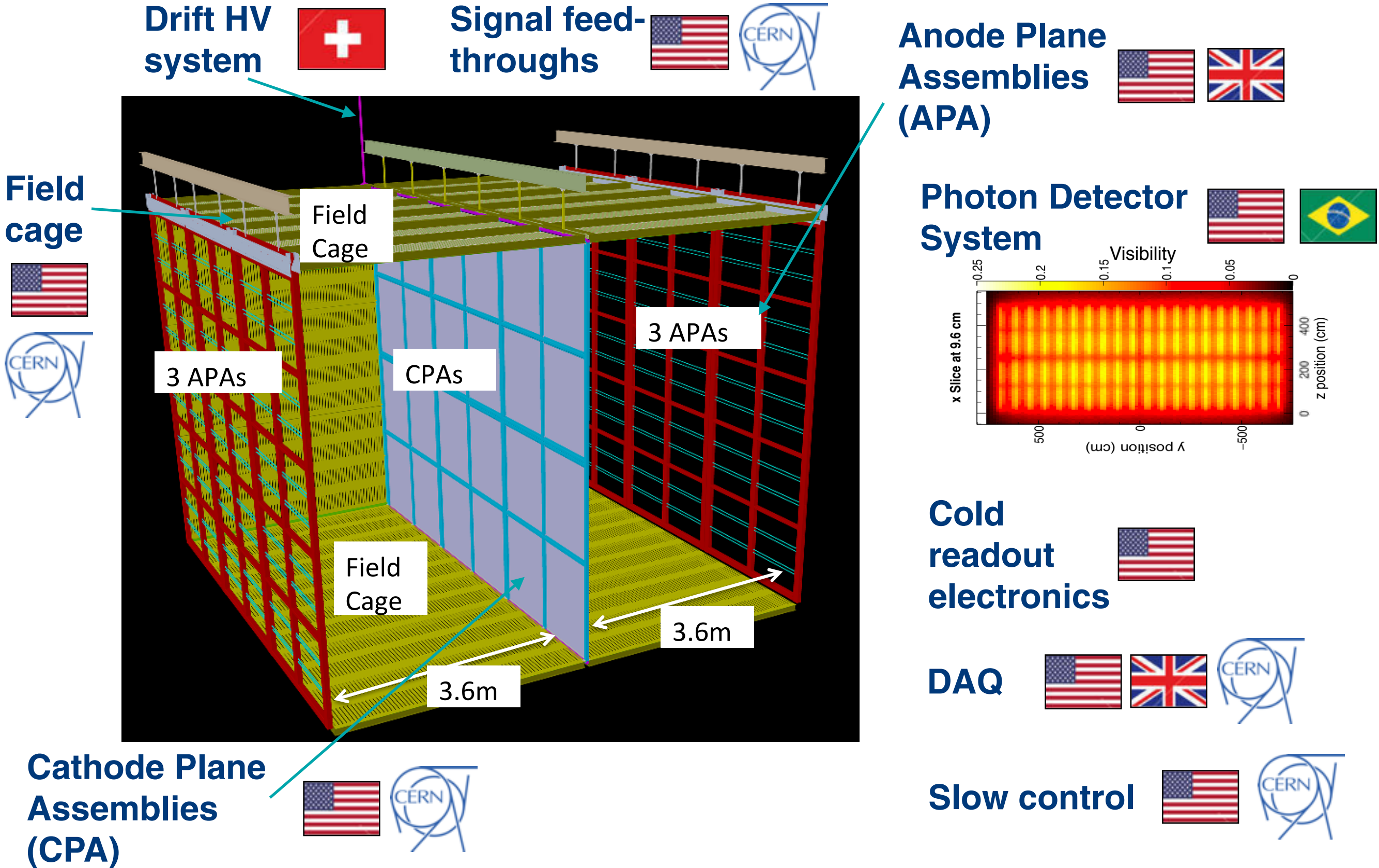
ProtoDune SP
detector

H4 beam line extension



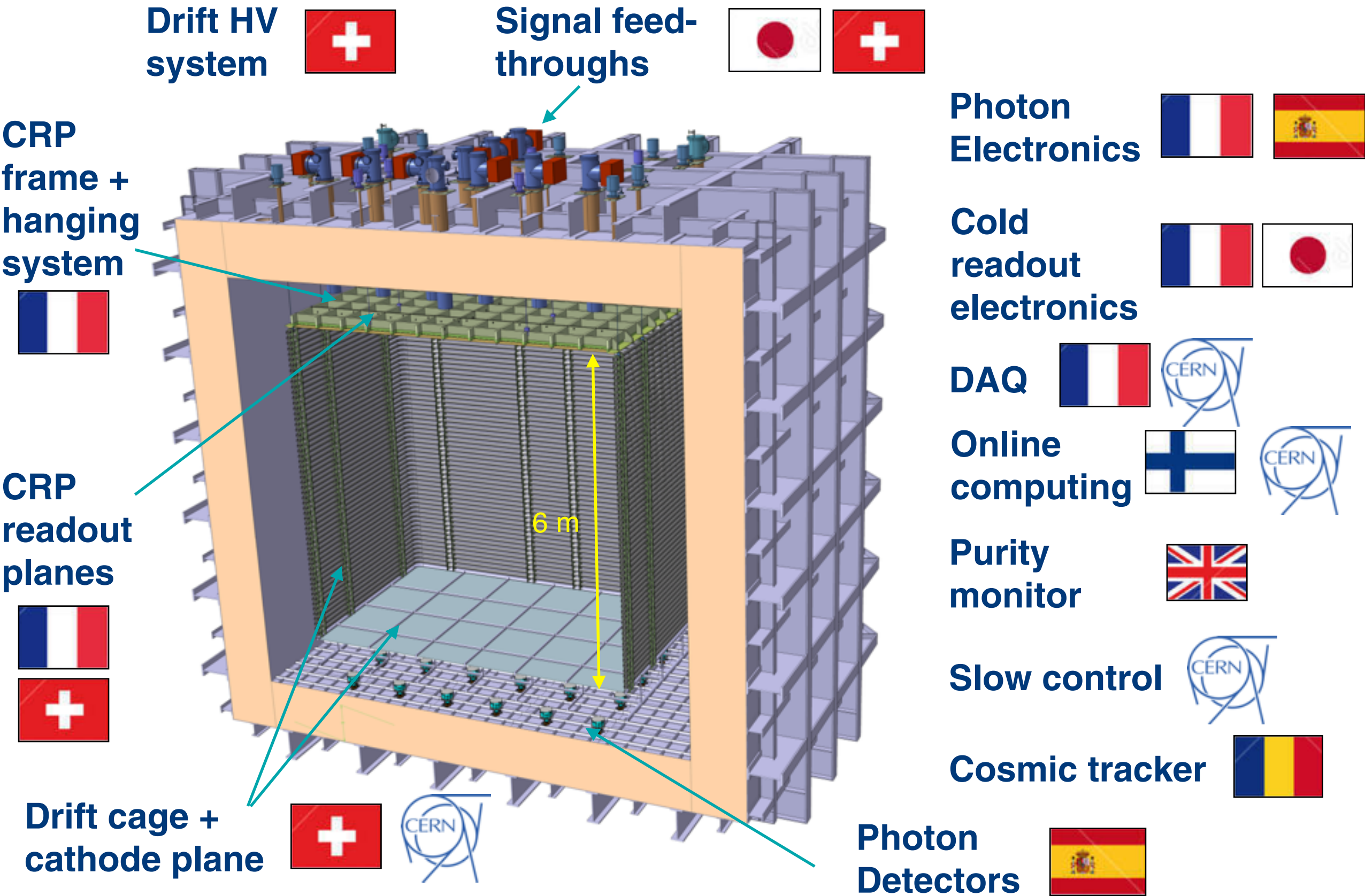
Single phase protoDUNE

(Non-DOE funding under negotiation)



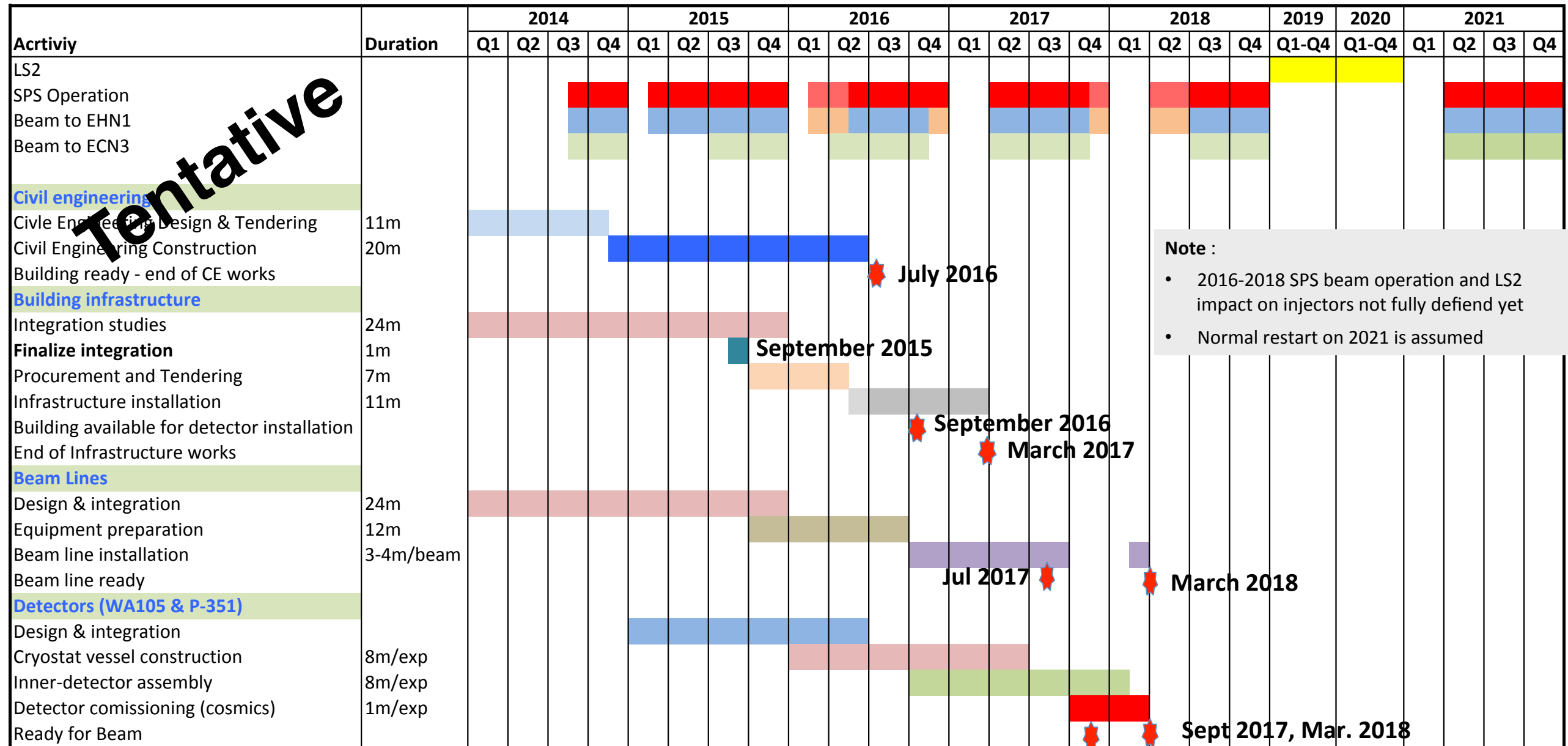
Dual phase protoDUNE

(Funding secured from FA and CERN MoU signed)



DUNE prototypes: timescale

Goal: assemble and take beam data with the single- and dual-phase prototypes before the long LS2 shutdown.



Next step: SP and DP schedules to be integrated and reconciled within the CERN EHN1 integration schedule. Confident we can reach our goal.

Integration of related R&D efforts

- **PAC commented**
 - *“DUNE should consider designating an R&D coordinator or coordination committee to integrate the many relevant R&D efforts that are not formally part of the DUNE project”*
- **Presently looking into several external proposals:**
 - CAPTAIN-MINERVA
 - Decay at Rest Neutrinos from NuMI
 - Possible Prototype for a High-Pressure Gaseous Argon TPC
 - Possible follow up with existing setups such as LArIAT, LAPD, 35T, ...
 - Possible use of specific small scale R&D facilities (HV test, purity, ...)
- **Held focussed session at the DUNE Collaboration in UTA, Arlington last week to provide forum for possible detector development activities with a connection to DUNE**
- **Discussions to continue - need to assess quantitative impact on DUNE of the various proposals (PAC's help welcome).**

Conclusion (I):

- DUNE/LBNF is moving quickly based on years of previous work at LBNE, LBNO, SURF and elsewhere to address the challenges of the next generation long-baseline experiments.
- We have rapidly emerged as a highly motivated, experienced and well-organised large international Collaboration, eager to start physics in early 2020's, within an incremental staging of far detector mass and beam power.
- The Working groups and Task Forces organisations have made significant progress in the last months. Manpower is being identified and is getting engaged. The prompt commitment of significant manpower resources represents a challenge and this should be one of our main focus at the moment.

The Collaboration is functioning effectively well at all levels, beyond “review mode”, making concrete progress on specific topics.

Conclusion (II):

- We are thrilled by the prospects of getting CD-3a approval in 2016.
- We are maintaining a strong connection to LBNF through the EFIG and the DUNE technical board & project management teams.
- The Working Groups should define detailed plans towards the next CD-2 milestone in 2019 with the aim of baselining the ND and FD detectors.
- The Technical Board and International Project Team are fully functional and meet regularly, recommending to EC and implementing technical decisions.
- The Collaboration Resource Board is in place and ready to make progress towards upcoming LBNF/DUNE RRBs.

We are eager to continue to making rapid scientific and technical progress – working towards readiness for a CD2 review around 2019.

Conclusion (III):

- The CERN Neutrino Platform offers a unique infrastructure for construction and test of large-scale LAr prototypes of the DUNE far detectors.
- Building the DUNE prototypes is essential to inform the Technical Design Reports due for the CD-2 review. Single and dual-phase prototypes are currently approved CERN projects. We need to secure a contingent of scientists and engineers based at CERN to reach the milestones in a timely manner.
- The setting up of the assembly(+QA/QC) chains and the validity proof of their installation sequences will effectively represent a real first step towards the construction of the DUNE FDs.

The protoDUNEs efforts at CERN - now fully integrated - are rapidly being organising and making very concrete progress. Their timely execution will represent an ultimate proof of our state of readiness for FDs deployment. Working to engage full Collaboration in these exciting & urgent activities.

Backup